

# **Linings of Aboveground Petroleum Storage Tank Bottoms**

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# Linings of Aboveground Petroleum Storage Tank Bottoms

## 1 Scope

This recommended practice (RP) provides guidance on achieving effective corrosion control in aboveground storage tanks by application of tank bottom linings. It contains information pertinent to the selection of lining materials, surface preparation, lining application, cure, and inspection of tank bottom linings for existing and new storage tanks. In many cases, tank bottom linings have proven to be an effective method of preventing internal corrosion of steel tank bottoms.

The intent of this RP is to provide information and guidance specific to aboveground steel storage tanks in hydrocarbon service. Certain practices recommended herein may also be applicable to tanks in other services. This RP is intended to serve only as a guide. Detailed tank bottom lining specifications are not included.

Because of the wide variety of service environments, this RP does not designate specific tank bottom linings for every situation.

NACE No.10/SSPC-PA 6 and NACE No. 11/SSPC-PA 8 are industry consensus standards for installation of linings on tank bottoms and vessels. They are written in compulsory language and contain specific criteria intended for use by persons who provide written specifications for tank and vessel linings. These documents should be given consideration when designing and installing a lining system for steel bottom tanks.

## 2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API Bulletin 939-E, *Identification, Repair, and Mitigation of Cracking of Steel Equipment in Petroleum Refineries and Petrochemical Plants*

API Recommended Practice 651, *Cathodic Protection of Aboveground Petroleum Storage Tanks*

API Standard 653, *Tank Inspection, Repair, Alteration, and Reconstruction*

API Standard 2015, *Requirements for Safe Entry and Cleaning of Petroleum Storage Tanks*

ASTM D4285,<sup>1</sup> *Standard Test Method for Indicating Oil or Water in Compressed Air*

ASTM D4414, *Standard Practice for Measurement of Wet Film Thickness by Notch Gages*

ASTM D4940, *Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives*

ASTM E96, *Standard Test Methods for Water Vapor Transmission of Materials*

ASTM G9, *Standard Test Method for Water Penetration into Pipeline Coatings*

NACE 37519,<sup>2</sup> *Corrosion Data Survey—Metals Section*

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<sup>1</sup> ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, Pennsylvania 19428-2959, [www.astm.org](http://www.astm.org).

<sup>2</sup> NACE International (formerly the National Association of Corrosion Engineers), 15835 Park Ten Place, Houston, Texas 77084, [www.nace.org](http://www.nace.org).

NACE SP0178, *Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service*

NACE No. 1/SSPC-SP 5, *White Metal Blast Cleaning*

NACE No. 2/SSPC-SP 10, *Near-White Metal Blast Cleaning*

NACE No. 10/SSPC-PA 6, *Fiberglass-Reinforced Plastic (FRP), Linings Applied to Bottoms of Carbon Steel Aboveground Storage Tanks*

NACE No. 11/SSPC-PA 8, *Thin-Film Organic Linings Applied in New Carbon Steel Process Vessels*

NACE 6A192/SSPC-TR 3, *Dehumidification and Temperature Control During Surface Preparation, Application, and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Spaces*

U.S. DOL Title 29, CFR Part 1910.132,<sup>3</sup> *Personal Protective Equipment, General Requirements*

U.S. DOL Title 29, CFR Part 1910.146, *Permit-Required Confined Spaces*

U.S. DOL Title 29, CFR Part 1926.62, *Lead (Construction Industry Standard)*

OSHA Publication 2254,<sup>4</sup> *Training Requirements in OSHA Standards and Training Guidelines*

SSPC Guide 15,<sup>5</sup> *Field Methods for Extraction and Analysis of Soluble Salts on Steel and Other Nonporous Substrates*

SSPC-PA 1, *Shop, Field, and Maintenance Painting of Steel*

SSPC-PA 2, *Procedure for Determining Conformance to Dry Coating Thickness Requirements*

SSPC-SP 1, *Solvent Cleaning*

SSPC-SP 11, *Power Tool Cleaning to Bare Metal*

### 3 Terms and Definitions

For the purposes of this document, the following definitions apply.

#### 3.1

##### **aboveground storage tank**

A stationary container, usually cylindrical in shape, consisting of a metallic roof, shell, bottom, and support structure where more than 90 % of the tank volume is above surface grade.

#### 3.2

##### **anchor pattern**

##### **anchor profile**

##### **profile**

##### **surface profile**

Surface contour or roughness of a blast-cleaned or substrate surface, when viewed from the edge.

<sup>3</sup> The Code of Federal Regulations is available from the U.S. Government Publishing Office, 732 N. Capitol Street, NW, Washington, DC 20401, [www.gpo.gov](http://www.gpo.gov).

<sup>4</sup> U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, [www.osha.gov](http://www.osha.gov).

<sup>5</sup> The Society for Protective Coatings, 800 Trumbull Drive, Pittsburgh, Pennsylvania 15205, [www.sspc.org](http://www.sspc.org).

**3.3****anode**

The electrode of an electrolytic cell in which oxidation is the principal reaction.

NOTE     Electrons flow away from the anode toward the cathode in the external circuit. It is usually the electrode where corrosion occurs, and metal ions enter solution.

**3.4****cathode**

The electrode of an electrolytic cell at which reduction is the principal reaction. Electrons flow toward the cathode in the external circuit.

**3.5****cathodic protection**

A corrosion control system in which the metal to be protected is made to serve as a cathode, either by the deliberate establishment of a galvanic cell or by impressed current. (See anode and cathode.)

**3.6****caulk**

Products used in order to fair or smooth surfaces, as well as seal seams and rivets in lining applications.

**3.7****coating**

A paint or other finish used to create a protective or decorative layer.

**3.8****concentration cell**

An electrochemical cell, the electromotive force (EMF) of which is caused by a difference in concentration of some component in the electrolyte, or electrolytes containing different substances.

NOTE     This difference leads to the formation of discrete cathode and anode regions.

**3.9****corrosion**

The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.

**3.10****corrosion protection**

The minimization of corrosion using linings for exposed steel surfaces and cathodic protection or vapor corrosion inhibitors for concealed tank bottom steel plate surfaces.

**3.11****cure, curing**

The process whereby a liquid coating becomes a hard film. Curing is complete when the lining is ready to accept immersion in the designated service.

NOTE     Methods of testing cure include solvent rub and hardness testing.

**3.12****dew point**

Temperature at which moisture will condense from vapors into a liquid state.

**3.13****differential aeration cell**

A concentration cell caused by differences in oxygen concentration along the surface of a metal in an electrolyte. (See oxygen concentration cell.)

**3.14****electrochemical cell**

An electrochemical system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte.

NOTE The anode and cathode may be different metals or dissimilar areas on the same metal surface.

**3.15****electrolyte**

A nonmetallic substance that carries an electric current or a substance which when dissolved in another medium, such as water, separates into ions which can carry an electric current.

**3.16****epoxy**

Extremely tough and durable synthetic coating resins that are highly resistant to chemicals, abrasion, moisture, and in some cases, alcohols.

**3.17****fiberglass-reinforced plastic****FRP**

Resin linings, usually polyester, vinyl ester, or epoxy into which layers of fiberglass are incorporated to optimize the lining's structural capability and performance. See NACE No. 10/SSPC-PA 6.

**3.18****forced curing**

Acceleration of curing by increasing the temperature above ambient, accompanied by forced air circulation.

**3.19****fretting corrosion**

Deterioration at the interface between contacting surfaces as the result of corrosion and movement between the two surfaces.

**3.20****holiday**

A discontinuity in a protective coating that exposes unprotected surface to the environment. Also refers to application defects whereby small areas are left uncoated.

**3.21****lining**

A liquid paint applied to the interior surfaces of a vessel that develops strong adhesion to the substrate and is designed for immersion service or vapor-space service for a specified stored product.

NOTE A lining can be reinforced or unreinforced.

**3.22****mil**

One one-thousandth of an inch (0.001 in.).

NOTE One mil = 25.4  $\mu\text{m}$ ; it is common practice to use 1 mil = 25  $\mu\text{m}$ .

**3.23****mill scale**

The heavy oxide layer formed during hot fabrication or heat treatment of metals, typically a black-blue colored smooth layer found on the surface.

**3.24****oxygen concentration cell**

A concentration cell caused by differences in oxygen concentration along the surface of a metal in an electrolyte. (Also referred to as: differential oxygen cell, or differential aeration cell.)

**3.25****phenolic**

A resin of the phenol formaldehyde type.

NOTE Phenolic and novolac epoxies tend to be more chemically resistant.

**3.26****primer**

First complete coat applied to the prepared surface.

NOTE Holding primers are often used in tank linings when operational issues require daily coating of the blasted surface.

**3.27****stress corrosion cracking****SCC**

The fracture of a metal by the combined action of corrosion and tensile stress. The fracture occurs under a tensile stress that may be well below the tensile strength or even the yield strength of the material.

**3.28****thick-film lining**

A lining with a dry film thickness (DFT) of 20 mils (500  $\mu\text{m}$ ) or more.

**3.29****thin-film lining**

A lining with a DFT less than 20 mils (500  $\mu\text{m}$ ).

**3.30****vinyl ester**

A chemically resistant resin frequently used in flake coatings as well as in the fiberglass-reinforced thick-film systems.

NOTE This product may contain styrene, which is on the hazardous air pollutants (HAPS) list and is a carcinogen.

**3.31****volatile corrosion inhibitor****VCI**

A type of corrosion inhibitor that is used to protect ferrous materials and non-ferrous metals against corrosion or oxidation, where it is impractical to apply surface treatments. It works by slowly releasing chemical compounds within a sealed airspace that actively prevents surface corrosion.

**3.32****volatile organic compound****VOC**

Compounds of carbon that have high vapor pressure and low water solubility.

NOTE VOCs typically are industrial solvents, fuel oxygenates, or components of petroleum fuels. VOC content in coatings is highly regulated. Specifiers should be aware of the jurisdiction and regulations in the geography where the coating is to be applied prior to specifying a coating product.

**3.33****water bottom**

A water layer in the bottom of a tank caused by separation of water and product due to differences in solubility and specific gravity.

## 4 Corrosion Mechanisms

### 4.1 General

Corrosion rates of carbon steel in various hydrocarbons have been determined and are given in many reference texts such as NACE 37519, *Corrosion Data Survey—Metals Section*. These rates apply only if there are no accelerating mechanisms. For example, corrosion would not be expected in ambient temperature crude oil or product service with no water present; however, corrosion may occur when a layer of water settles to the bottom of a crude oil intermediate product or finished product storage tank. This water, which may enter the tank with the product, through the seals, or during “breathing” of the tank, often contains corrosive compounds. For example, crude oil may contain saltwater and sediment that settles out on the bottoms of storage tanks. Chlorides and other soluble salts contained in the water may provide a strong electrolyte that can promote corrosion. The common mechanisms of internal tank bottom corrosion include:

- a) chemical corrosion,
- b) concentration cell corrosion,
- c) oxygen cell corrosion,
- d) galvanic cell corrosion,
- e) microbiologically influenced corrosion (MIC),
- f) erosion-corrosion,
- g) fretting-related corrosion,
- h) general vs localized pitting,
- i) stress corrosion cracking.

These mechanisms are discussed in detail in the following sections.

### 4.2 Chemical Corrosion

Chemical corrosion may occur in environmental and product cleanup tanks as well as in chemical storage facilities. For example, a wastewater treatment tank operates by adding heat and/or concentrated sulfuric acid to the water to break the emulsion of oil and water. The acid, unless added properly, immediately becomes diluted and hence much more corrosive, especially in the area of the acid inlet piping. Chemical attack is also prevalent in corrosive services such as caustic, sulfuric acid, ballast water, and water neutralization services. Proper coating selection is crucial when considering this type of service. This type of attack can also be associated with locations in close proximity to chemical injection points involving chemicals such as inhibitors and biocides.

### 4.3 Concentration Cell Corrosion

Concentration cell corrosion may occur when the steel tank bottom is in contact with electrolytes that contain different substances or the same substance in differing amounts. For example, if one electrolyte is a dilute salt solution and the other a concentrated salt solution, a concentration cell may be formed. When the salt is a simple one and is not a salt of the metal, the portion of the tank bottom in contact with the more concentrated solution will be the anode. Concentration cell corrosion will cause pitting and may result in significant localized metal loss. Pitting of a bare steel tank bottom may occur at a rate as high as 80 mils (2032  $\mu\text{m}$ ) per year.

#### 4.4 Oxygen Cell Corrosion

Oxygen cell corrosion may occur when a surface deposit, mill scale, or crevice creates a localized area of lower oxygen concentration. The area under a surface deposit may be penetrated by a thin layer of electrolyte, which soon becomes depleted of oxygen. The difference in oxygen concentration between the inaccessible area and the bulk electrolyte creates a galvanic cell, with the contact area of the surface deposit being anodic to the surrounding tank plate.

#### 4.5 Galvanic Cell Corrosion

Hot-rolled carbon steel, typically used for the construction of petroleum storage tanks, is covered with a thin layer of oxide called mill scale, which is cathodic to the base steel. In the presence of a corrodent (such as dissolved oxygen) and an electrolyte, a galvanic corrosion couple forms at breaks in the mill scale. Accelerated pitting corrosion of the steel at breaks in the mill scale can result. Mill scale may be removed from both sides of the tank bottom plate by abrasive blast cleaning or by pickling, but removal of mill scale from the soil-side of the steel bottom is not commonly done. Removal of mill scale from the soil-side of new steel bottoms may be considered in an effort to promote a more uniform corrosion and minimize accelerated pitting corrosion that may occur.

In some cases, welding can produce large differences in the microstructure of a steel bottom plate, resulting in a built-in galvanic couple. In the presence of a corrodent and an electrolyte, preferential corrosion can occur at the heat-affected zones (HAZ) of the base metal near the welds. This type of corrosion can cause significant localized metal loss.

Such a condition can also be created where new steel is installed alongside older steel that is in effect passivated by surface corrosion products, calcareous deposits and or surface contaminants such as a hydrocarbon film. Mismatched materials can also create galvanic cell corrosion issues.

#### 4.6 Microbiologically Influenced Corrosion (MIC)

Bacteria (e.g. sulfate reducing bacteria [SRB] and acid producing bacteria [APB]) are widespread in the petroleum industry. The role of bacteria in corrosion is universally recognized but the mechanisms are not well understood. Generally, the effect of bacteria on the corrosion of bare steel tank bottoms is negligible. In some cases, however, severe corrosion has been attributed to MIC. The bacteria colonies form deposits on the steel that may provide an effective barrier to the diffusion of dissolved oxygen. Thus, the mere physical presence of bacterial deposits can promote aggressive pitting corrosion by the concentration cell mechanism described in 4.3.

The metabolism of bacteria is important regarding the corrosion of storage tank bottoms. Most bacteria found in the petroleum industry are strict anaerobes that do not proliferate in the presence of oxygen; however, the dense bacterial colonies create a local anaerobic condition, even if some oxygen is available. By creating the local anaerobic condition, the bacteria can stay alive in the presence of oxygen, even though the colonies do not expand. In the case of SRB, colonies derive energy principally from the reduction of sulfates to sulfide, and this metabolic end product is corrosive to steel. Moreover, the iron sulfide corrosion product is cathodic to the base steel and may promote accelerated pitting corrosion by a galvanic mechanism, as described in 4.4, if dissolved oxygen is available as a corrodent. This type of corrosion can often be found in tanks containing crude oil, ultra-low sulfur diesel, fuel oils, and aviation fuels.

**CAUTION—Owner/operator operators have experienced severe MIC in recent years with isolated accelerated corrosion on uncoated tank bottoms far in excess of the average corrosion rates.**

#### 4.7 Erosion-corrosion

Erosion-corrosion may occur in wastewater treating or mixing tanks where soil or small abrasive aggregate is present. To a lesser extent, erosion-corrosion can also occur at tank mixers in crude oil storage tanks. A water treatment tank blends chemicals into contaminated water to break any emulsions of oil and water. Agitation may increase corrosion by delivering more corrodent, such as dissolved oxygen, from the bulk of the stored product to the surface of the tank steel. Turbulence also moves any fine aggregate that is present, creating an abrasive environment in which adherent, semi-protective corrosion products can be dislodged, exposing the

underlying steel to the corrosive environment. Severe erosion conditions may scour the base metal directly. Erosion-corrosion causes highly localized metal loss in a well-defined pattern. Erosion-corrosion may be found at tank inlets and outlets where product flow occurs.

#### 4.8 Fretting-related Corrosion

Fretting-related corrosion may occur in hydrocarbon service on the bottoms of external floating roof tanks. When the tank is emptied, the floating roof is typically supported on roof-support legs constructed of open-ended pipe. Most bottom designs require “striker plates” under each roof support leg. When the floating roof is landed, the pipe legs rest on the striker plates supporting the weight of the roof. Repeated, frequent contact between the striker plate and the open end of the pipe leg removes any protective layer of rust scale that may have formed on the striker plate surface. When the roof is floated again, any water on the tank bottom causes corrosion at the location on the striker plate where the coating and/or any protective rust scale has been damaged. Experience has shown that frequent roof landings over a long period of time causes corrosion severe and localized enough to corrode a hole through the striker plate and the bottom plate like a cookie cutter cuts dough.

#### 4.9 Generalized vs Localized (Pitting) Corrosion

Two common types of corrosion found on tank bottoms are general and localized (pitting) corrosion. In general corrosion, thousands of microscopic corrosion cells occur on an area of the metal surface resulting in relatively uniform metal loss. In localized (pitting) corrosion, the individual corrosion cells are larger and distinct anodic and cathodic areas can be identified. Metal loss in this case may be concentrated within relatively small areas with substantial areas of the surface unaffected by corrosion. Corrosion of this type can often be found when MIC is present.

#### 4.10 Stress Corrosion Cracking

Stress corrosion cracking (SCC) has been identified in tanks storing fuel grade ethanol. Owner/operators should take measures to protect welds from this phenomenon. One method identified to prevent SCC is to coat welds with internal lining materials. This would typically include the bottom and lower shell welds, which are coated when the complete bottom is coated, or may include additional welds on the immersed surface of the shell, at the discretion of the owner/operator.

#### 4.11 Internal Corrosion Mechanisms

The extent or nature of corrosion on tank bottoms depends on many factors associated with the composition of the fluid in contact with the steel bottom. Major factors include:

- a) conductivity (a function of dissolved solids);
- b) suspended solids;
- c) pH;
- d) dissolved gases such as CO<sub>2</sub>, H<sub>2</sub>S or O<sub>2</sub>;
- e) sulfate reducing bacteria;
- f) temperature.

To a lesser extent, stress corrosion cracking has been found when storing certain products. Stress corrosion cracking is discussed in API Bulletin 939-E.

## 5 Determination of the Need for Tank Bottom Lining

### 5.1 General

The bottom plates of aboveground storage tanks are susceptible to internal and external corrosion. Storage tank bottoms are generally fabricated from carbon steel plate sections that are typically 0.25 in. (6 mm) thick. Annular bottom plates of storage tanks frequently have thicker plate sections ranging from 0.25 in. to 1.0 in. (6 mm to 25 mm). The bottom plate sections and the attachment fillet lap welds are intended to function as a membrane and prevent leaks. Uniform soil support beneath the bottom plate minimizes stress in the bottom plate.

The need for an internal tank bottom lining in an aboveground storage tank is generally based on several considerations:

- a) corrosion prevention;
- b) tank design;
- c) tank history;
- d) environmental considerations;
- e) reduction of time and effort for future tank cleaning;
- f) federal, state, and local regulations;
- g) product quality; and
- h) considerations under API Standard 653 with respect to next inspection interval.

### 5.2 Linings for Corrosion Protection

The proper selection, application, and maintenance of tank bottom linings can prevent internal corrosion of the steel tank bottom. However, unless means of corrosion prevention are used on the soil side, perforation of the tank bottom may still occur.

The minimum thickness of the steel tank bottom should be determined according to API 653. An internal tank bottom lining may be deemed necessary if corrosion is expected to proceed such that the steel thickness may reach this minimum thickness, generally 0.100 in. (2.5 mm), prior to the next scheduled inspection.

If the minimum bottom thicknesses at the end of the in-service period of operation are calculated to be less than the minimum bottom renewal thicknesses given in API 653, or less than the minimum bottom renewal thicknesses providing acceptable risk as determined by an RBI assessment per API 653, the tank bottom shall be lined, repaired, replaced, or the interval to the next internal inspection shortened.

When using API 653 to determine appropriate internal inspection intervals for aboveground storage tanks, the anticipated life of the lining as well as the corrosion rate anticipated in the event of premature lining failure should be considered.

### 5.3 Tank Corrosion History

The corrosion history of a particular tank should be considered when determining the need for an internal lining. The corrosion history of tanks in similar service should also be considered. The items to be considered are dictated by individual circumstances, but some of the more important considerations are as follows.

- a) Where is the corrosion occurring (product-side, soil-side, or both)?

- b) What is the internal and soil-side corrosion rate?
- c) Have there been significant changes in the corrosion rates?
- d) Is the corrosion uniform or localized?
- e) Has corrosion caused perforation of the steel tank bottom from the product-side, soil-side, or both?
- f) What was the prior service of the tank and how corrosive was that product?
- g) Were the tank internals protected with cathodic protection and, if so, what type and where (see NACE SP0388 and NACE SP0575)?
- h) What were the water bottom volumes, draw-down frequencies, tests performed, and results, if any?
- i) Were inhibitors or biocides used internally and, if so, what type, for how long, what type of application was used, and where were they introduced?
- j) Was the tank bottom constructed or modified welded, riveted, flat, cone-up, cone-down, “w” type, double bottom, or with any sump(s)?
- k) Was environmental cracking ever identified (e.g. stress corrosion cracking [ethanol-related])?

There is a need to evaluate both the internal (product-side) and soil-side tank bottom corrosion aspects in tandem. Soil-side corrosion on a tank bottom can influence decisions related to out-of-service inspection intervals and product-side lining (initial application), relining (replacement), lining repairs and overcoats, as well as overall tank bottom replacements based on actual or potential extensive soil-side corrosion and/or the need to replace or modify pad materials or soil-side cathodic protection systems or components. Therefore, the following should also be considered:

- 1) Was the soil-side protected with cathodic protection and, if so, to what level and during what period (see API 651)?
- 2) What is the age and condition of any existing cathodic protection system?
- 3) Were volatile corrosion inhibitors (VCIs), other inhibitors or biocides injected under the tank bottom and, if so, during what period?
- 4) What are the tank foundation and pad materials, and their configurations?
- 5) Were there any periods of standing water inside the tank secondary containment (i.e. inside dikes/berms) or is the water table right up at the level of the tank bottom or its pad?

## 5.4 Tank Foundation

The foundation must be adequate to prevent excessive settlement of the tank. If uniform foundation support is not provided, flexing of the tank bottom can result as the tank is filled or emptied. Flexing occurs on all steel bottoms; however, excessive flexing of the steel bottom may cause an internal bottom lining to crack.

# 6 Tank Bottom Lining Selection

## 6.1 General

Tank bottom linings can generally be divided into two classes: thin-films (with a DFT less than 20 mils [500 µm]) and thick-films (with a DFT of 20 mils [500 µm] or more). Linings may be applied to the bottoms of storage tanks

when they are first constructed, or they may be installed after some period of service. The advantages and disadvantages of thin- and thick-film tank bottom lining systems are discussed in this section.

Most tank bottom lining materials are initially selected based on chemical resistance or compatibility with the stored product. However, resistance to moisture permeation should also be a major consideration for long-term service since most storage tanks will typically have a layer of water on the bottom. All lining materials absorb moisture over time and this absorption can ultimately result in their failure. The moisture vapor transmission of various lining materials can be comparatively tested using ASTM E96, ASTM G9, or other equivalent test methods. Because tank bottoms flex during operation, a bend test on each coating candidate should be performed to ASTM standards prior to coating selection (see ASTM D522).

Recent advancements in technology have produced coatings with zero or near-zero VOCs. These 100 % solids coatings provide reduced safety concerns during application, can be applied in a single coat, and offer a reduction in the tank turnaround schedule. With some exceptions, these coatings are classified as thick-film linings, although some 100 % solids coatings may be applied as thin-film linings where the added thickness is not required.

## **6.2 Inorganic Zinc/Zinc Silicate (IOZ)**

### **6.2.1 General**

Inorganic zinc (IOZ), also known as zinc silicate, is a type of coating that can be used as a tank lining for ethanol and methanol storage. IOZ is different from organic coatings in many respects. IOZ is typically applied at 3 mils to 5 mils (76  $\mu\text{m}$  to 127  $\mu\text{m}$ ) dry DFT. It is applied in only one coat and relies on moisture for curing and must be applied by a spray process. IOZ chemically bonds to the steel substrate in a different manner from organic coatings, e.g. epoxies. Coating manufacturers may require a specified level of loading when this coating is used as a tank lining.

In common with organic coatings, IOZ should be applied after an SP-10 near white blast minimum surface cleanliness for successful application as an internal lining.

### **6.2.2 Advantages of IOZ**

IOZ has several advantages over organic coatings for internal lining:

- 1) The nature of the zinc metal in the coating and the lack of organic binders and resins indicates that a metallic bond can form between the zinc and the steel, resulting in remarkable corrosion protection with the anodic zinc adjacent to the metallic steel;
- 2) Excellent adhesion to the steel substrate;
- 3) Can be applied and cured at much lower temperatures than organic coating;
- 4) Almost immediate curing at ambient temperature conditions;
- 5) Preferred product by many manufacturers for internal lining of tanks storing solvents such as ethanol or methanol.

### **6.2.3 Disadvantages of IOZ**

IOZ has several disadvantages over organic coatings for internal lining:

- 1) It is only able to be applied in a one coat application as it does not exhibit good adhesion to itself. If the coating is applied at the incorrect film thickness at the original application, it is difficult to remedy.

- 2) If the application is too thin (i.e. less than 3 mils [76  $\mu\text{m}$ ]), there is inadequate protection of the steel and the steel can flash rust. If the application is too thick (i.e. greater than 5 mils [127  $\mu\text{m}$ ]), the coating will mud crack and can disbond immediately after application.
- 3) Because IOZ coatings have metallic pigment and are electrically conductive, they cannot be tested using conventional holiday test methods. Both low-voltage and high-voltage test equipment rely on an internal lining that is electrically non-conductive and in the case of high-voltage testing has adequate di-electric strength for the test to occur without coating damage.
- 4) IOZ coatings are not suitable for steel that has any more than just a slight amount of surface pitting. Steel that exhibits moderate or severe pitting and especially steel with omega shaped pits would not be suitable for a successful application.
- 5) IOZ coatings are not suitable for acidic applications, as metallic zinc metal will move into solution in the presence of acid. pH range is limited.
- 6) Need presence of moisture to cure, which may be difficult in certain climates and seasons.
- 7) Requires a highly skilled applicator to meet the strict film thickness parameters during application.
- 8) Use of IOZ linings can affect product purity.

#### **6.2.4 Inorganic Zinc as a Thin-film Lining for Petroleum Storage per API 653**

Because they are applied below 20 mils (508  $\mu\text{m}$ ) DFT, based on thickness, IOZ belongs in the category of a thin-film lining. However, due to these many limitations stated above, IOZ coatings applied to internal tank bottoms are not currently considered internal linings for purposes of the inspection calculation requirements in API 653 when storing petroleum products.

In addition, because of the potential for immiscible water in contact with the steel along with the potential of MIC which can result in the presence of acids, IOZ should not be considered a suitable internal lining material for purposes of API 653 for tanks storing petroleum products.

Notwithstanding the above, IOZ has been successfully applied to new steel bottoms and steel that is only slightly pitted with minimal product-side corrosion for petroleum storage. It is still a viable internal lining and can provide protection from corrosion even if there is no credit being given for zero corrosion rate on the product side per API 653, provided there are no sources of acids from the service.

### **6.3 Thin-film Tank Bottom Linings**

#### **6.3.1 General**

Thin-film tank bottom lining systems are frequently based on epoxy or epoxy-copolymer resins. All linings that are employed to protect tank bottoms also must be resistant to water, since water will normally be present at the tank bottom allowing electrochemical corrosion to occur. NACE No. 11/SSPC-PA 8 should be given consideration when designing and installing a thin-film lining system for steel bottom tanks.

#### **6.3.2 Advantages of Thin-film Linings**

Thin-film lining systems are often used for application to the product side of the bottoms of new storage tanks. New steel plates provide a smooth surface that can easily be made ready for lining application. Corrosion of bare steel tank bottoms is rarely uniform. Generally, corrosion due to immersion exposure creates a surface that is rough and pitted, often making it difficult to completely coat and protect corroded steel bottom surfaces with a thin-film lining system. The principal advantages of thin-film linings are as follows:

- a) Initial cost is typically less than reinforced thick-film linings.

- b) Most are easier to apply than reinforced thick-film linings.
- c) Experience has shown that when properly selected and applied to properly prepared surfaces, and not damaged, the life of thin-film linings can be greater than 20 years.
- d) Most thin-film epoxy linings exhibit good flexibility.
- e) Allows for more accurate magnetic flux leakage (MFL) bottom scans.
- f) It is often easier to remove a thin-film lining at the end of its useful life.
- g) A thin-film lining may be all that is needed to prevent internal corrosion from occurring based on the condition of the steel substrate.
- h) Thin-film linings are easier to repair than fiberglass-reinforced linings.

### 6.3.3 Disadvantages of Thin-film Linings

Limitations of thin-film linings include the following:

- a) API 653 only allows the bottom plate thickness to be a minimum of 0.100 in. (2.5 mm) at the time of the next internal inspection interval.
- b) Thin-film linings are more susceptible to mechanical damage than thick-film linings.
- c) Rough weld surfaces, weld spatter, sharp component edges or corners, and rough or sharp areas of corrosion can protrude well into or through the finished lining thickness or create a lack of edge retention and result in holidays. Therefore, weld surfaces, edges, corners, and corrosion areas should be relatively smooth and rounded, with weld spatter removed before such a lining is applied. If it is not feasible to create relatively smooth or rounded edges, corners, and corrosion areas while removing weld spatter through grinding, weld repair, and/or other processes, then caulking, thick-film coatings, or multiple coats of appropriate thin-film coatings may be considered as an alternative to create a film free from holidays. Optimally, requirements for weld surface quality are part of the welding specification and not part of the lining contractor's responsibility, unless otherwise specified by the owner/operator. See NACE 10/SSPC-PA 6, *Fiberglass-Reinforced Plastic (FRP) Linings Applied to Bottoms of Carbon Steel Aboveground Storage Tanks*, for information on caulking and NACE SP0178, *Fabrication Details, Surface Finish Requirements and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service*, for information regarding preparation for edges and corners, as well as welds.
- d) Some thin-film linings require the application of multiple coats as their normal application. In some cases, where appropriate, multiple coats of some thin-film coatings can even be advanced into the thick-film overall thickness and service life realms, where that approach is proven for such applications of those specific thin-film coating(s). In these cases, each individual separate coat needs to comply with the recoat window before applying the next coat.
- e) Thin-film linings are most often solvent-borne coatings that require the evaporation of solvent from the film to achieve proper cure. Solvent vapors are heavier than air. If they are not effectively removed from the tank or vessel, they will hover at the bottom level and impede the progress of the cure. VOC regulations shall be considered when specifying thin-film coatings. Presence of moisture in the air during the cure can cause amine blush, which must be removed before the application of subsequent coats. Amine blush can cause issues with intercoat adhesion if not properly removed between coats.

## 6.4 Thick-film Unreinforced Tank Bottom Linings

### 6.4.1 General

Thick-film unreinforced linings may be used as tank bottom linings for both new and existing storage tanks.

### 6.4.2 Advantages of Thick-film Unreinforced Linings

Advantages of thick-film unreinforced linings include the following.

- a) Some thick-film linings can be built up to 100 mils (2540  $\mu\text{m}$ ) in a single coat.
- b) Better film build over rough surfaces.
- c) No overlap joints, intercoat contamination or amine blushing issues with a single coat application.
- d) May have better edge retention with reduced material shrinkage. Edge retention may be a disadvantage on pitted bottoms.
- e) Typically, fast curing, with the ability to be returned to service quickly resulting in a shorter turnaround schedule.
- f) Fewer or no discontinuities to repair following holiday testing.
- g) Reduced labor costs compared with multiple coat thin-film or some labor-intensive reinforced thick-film linings.
- h) Long-term service—may be greater than 20 years resulting in low life-cycle costs.
- i) Generally, provides greater resistance to moisture permeation due to greater thickness.

### 6.4.3 Disadvantages of Thick-film Unreinforced Linings

Limitations of thick-film unreinforced linings include the following:

- a) May require the use of plural component spray equipment.
- b) Difficult to install on complex geometry due to plural component application.
- c) Plural component applied products may not be back-rolled into pitted bottoms easily.
- d) Requires experienced contractors and work crews.
- e) Ability to use magnetic flux leakage (MFL) floor scan inspection methods may be limited on linings of very high thickness.
- f) Depending on resin type and thickness, cracking due to plate flexure may be a concern.
- g) On pitted bottoms, product may not flow readily into deep pits, resulting in trapped air and pinholing.

## 6.5 Reinforced Thick-film Tank Bottom Linings

### 6.5.1 General

There are currently two systems being specified to restore heavily corroded and pitted tank bottoms: fiberglass-reinforced plastic (FRP) laminates and reinforced thick-film linings. FRP laminates and reinforced thick-film linings are methods to extend the life of these types of steel tank bottoms.

FRP systems consist of either a 1.5 oz. glass mat or chopped fiberglass roving embedded in a resin, typically either polyester, vinyl ester, or epoxy. Hand lay-up systems with fiberglass mat do not require special equipment and can be applied with a “dump and roll method.” A “chopped system” with glass roving requires heated plural spray equipment and a chopper gun to cut the glass roving and disperse it into the resin as it is being sprayed onto the bottom. Chopped systems require specific applicator expertise, as the device held and controlled by

the applicator must deposit not only the correct ratio of components in the resin mixture, but also the correct proportion and distribution of fibers in the resin.

FRP composites require multiple installation steps that include, in addition to blasting and priming, caulking of all weld seams and shell-to-bottom welds for smooth transition of glass, fabrication of the laminate with either glass mat or glass roving with the appropriate resin, and finally a protective gel coat of resin to ensure complete wetting of the glass to prevent wicking problems.

Reinforced thick-film linings that are not FRP composites are available because of coating technology advancements. These new flake- and fiber-reinforced thick-film lining systems are suitable for tank bottom restoration. These materials may be spray applied in one coat from 20 mils to 150 mils (508  $\mu\text{m}$  to 3810  $\mu\text{m}$ ) DFT over a blasted and primed bottom that greatly reduces their installation costs, relative to FRP laminates. One coat application also enhances tank turnaround time and removes intercoat adhesion issues common with improperly installed laminates and wicking issues that have occurred with improperly wetted glass fibers. Reinforced thick-film lining system manufacturers typically recommend heated plural equipment for proper application, which requires specialized equipment and applicator expertise.

Any of the systems described above are suitable for tank bottom restoration when poor steel conditions are found. Information related to the performance limitations of specific coatings regarding chemical immersion, elevated exposure temperatures, and low temperature application should be obtained from the coating manufacturer. A final decision requires a determination of the current extent of product side corrosion, thickness of the tank bottom, and a judgment on the potential for soil-side corrosion based on tank specific historical information.

While API 653 does not allow an inspection interval at the end of which the steel may be less than a minimum thickness of 0.050 in. (1270  $\mu\text{m}$ ) with a reinforced thick-film liner installed, the use of reinforced thick-film linings may provide additional protection in the event that a minor perforation occurs.

### **6.5.2 Advantages of Reinforced Thick-film Linings**

- 1) Systems are designed to optimize the linings' structural capability and performance.
- 2) Additional service life of the existing tank bottom due to the reduced minimum thickness allowed remaining.
- 3) Small damaged areas can be easily repaired.
- 4) Some formulations are fairly wear-resistant.

### **6.5.3 Disadvantages of Reinforced Thick-film Linings**

- 1) Initial cost is typically higher and systems are more difficult to apply than thin-film systems and thick-film unreinforced systems.
- 2) Must take additional safety precautions working around glass mat or chopped fiberglass material, (e.g. gloves should be cut as well as chemically resistant).
- 3) Application time requiring correct resin mixing with initiators, promoters, accelerators, and gel time retarders that must be carefully controlled and may influence final chemical resistance and application of laminate or lining.
- 4) Higher degree of application expertise needed to avoid problems with lay-up, air entrapment, and improper wetting out of glass fibers in the laminate.
- 5) May be sensitive to thermal shock, bending moments, and impact.
- 6) Glass fibers of laminates may act as a wicking path for product where exposed. Initial design should terminate laminates away from critical zones of the vessel and at an adequate level away from tank bottom.

- 7) MFL and other scanning methods including UT prove-up of bottom indications are more difficult through a reinforced thick-film lining.
- 8) FRP laminates and reinforced thick-film linings can be much more difficult to remove and repair or replace compared with thin-film and thick-film unreinforced lining systems.
- 9) FRP laminates can over time start to pull away from the vertical shell surfaces at the outer edges of those systems, due to slight system shrinkage, differential thermal expansion and contraction between the FRP laminate and the steel bottom/shell, tank flexure during filling and emptying, and water or other fluid migration along and into those areas. This condition can potentially allow water into the shell-to-bottom corner area, which, in turn, can then create a corrosive environment in those locations. These same conditions can develop along other liner edges, in liner wicking areas and in corrosion full penetration areas. The disbanding in these locations tends then to progress/expand outward under adjoining lining areas over time. Therefore, those areas are specific areas of focus during out-of-service inspections.

## **6.6 Circumstances Affecting Lining Selection**

### **6.6.1 General**

In addition to corrosion history and the potential for corrosion, other circumstances that must be taken into account during the selection of a tank bottom lining are described in 6.6.2 through 6.6.7.

### **6.6.2 Temperature**

Temperature must be considered during the selection of an internal lining system. Internal steam coils, which are used to heat a product to maintain a desirable viscosity, limit accessibility to the tank bottom during surface preparation and application of the lining. As a result, a good quality installation may be difficult to achieve. In service, steam coils create local areas where the temperature can be much greater than that of the bulk product. The resulting thermal effects on a tank bottom lining may cause localized coating damage such as blistering or cracking. The distance between the coils and the tank bottom is an important factor in determining the temperatures to which the coating may be exposed. If the coils are adequately close to the tank bottom, heat may be conducted into the bottom especially if there is any sludge build up over the service life of the tank. Storage tanks may operate above ambient temperature to maintain low viscosity of the stored product. As temperatures increase, this situation becomes more problematic and the need for careful lining selection is required. Information related to performance limitations with elevated service temperatures may be obtained from the lining manufacturer. The owner/operator should always consult the manufacturer for coating selection, suitable service, temperature limitations, and curing schedule and testing procedure.

### **6.6.3 Product Quality**

With many refined products, such as gasoline, jet fuel, lubricating oils, solvents, and other petrochemical products, tank bottoms may be lined not only to prevent internal corrosion but also to maintain product quality. If lining selection is principally based on product purity and the steel is in suitable condition for proper application of a thin-film lining, thin-film lining systems may be suitable to fulfill this need. However, in some circumstances a combination of product quality and corrosion resistance must be considered. Coatings that are certified to MIL-PRF-23236D for fuel service must meet a range of test requirements that are designed to ensure that a lining does not negatively impact key properties of jet fuel and aviation gasoline.

The owner/operator may also have to evaluate the product immersion liquid to ensure that product contamination by the prospective internal lining will not occur. Certain products, such as fiber-grade ethylene glycol, methanol, and other solvents have quality requirements that can be affected by solvent residues leaching from a newly applied lining into the stored product. In the case of ethylene glycol, these contaminants (even at very low levels) can interfere with the quality control tests for the high purity fiber-grade ethylene glycol (used in the manufacture of polyurethane fiber). In situations such as this, linings should be evaluated to determine their suitability for the intended service. Linings intended for product quality and corrosion protection must be resistant to the intended tank service and the probable presence of a contaminated water layer on the bottom. The manufacturer shall be

advised of the type of testing for product contamination to which the lining will be subjected to determine if the lining selection is suitable for the service.

#### 6.6.4 Presence of Tank Internals

Tanks may have design and fabrication features that make the application of a lining impractical or can seriously jeopardize the integrity of a lining. Examples of this include the coil supports and striker plates and cone roof legs. The details for the termination of the coatings where these features are encountered are critical to a good installation. For example, steel reinforcing and striker plates should be fully welded to the tank bottom, where feasible. Bottom coatings can properly be terminated on these reinforcing plates. The owner/operator can select to coat or not coat items such as cone roof columns and coil supports that are designed to be free from connection with the bottom or are designed to be self-centering. When electing to terminate a coating on a bottom reinforcing plate at or near a component feature, it is important that the surface preparation be performed to the specification beyond the location of the coating termination. The coating should be terminated on the reinforcing plate no less than 2 in. (51 mm) from any weld, if feasible. If it is suggested to coat the striker plates, the coating should be performed before the plates are installed, leaving the weld areas for field coating application.

#### 6.6.5 Flexibility for Service Change

Changes in tank service may affect the performance of an existing tank bottom lining. Tank linings do not offer universal resistance. A properly applied tank bottom lining may provide more than 20 years of service life in storing a particular product. A lining that has provided many years of satisfactory protection in one product may have inadequate resistance to a new service environment. The need for operational flexibility at some facilities requires that some tanks be available for swing service. Such factors should be considered during the selection and design of a lining system. Consult the manufacturer to determine if there are any specific recommendations (e.g. cleaning, ventilation, leaving the tank out of service for a specified time between different products, etc.) when changing the stored product.

#### 6.6.6 Construction Details That Can Impact the Lining

It is difficult to achieve lining continuity when irregular surfaces caused by discontinuous connections such as rivets, butt straps, and skip welding exist because they are difficult to cover and protect with a lining. In old tanks, the problem of poor film build may be complicated by chemical contaminants, which may be difficult to remove. It is common to use caulk to seal lap joints between riveted plates and around rivets before or after coating/lining in order to provide a continuous surface for the lining application. In determining whether the caulking should be applied before or after the lining, the more flexible material should be applied last. Caulking should be selected and specified based on the conditions encountered with consideration for the temperatures and the tank service requirements. Welded tanks generally require less preparation than riveted tanks. See NACE 10/SSPC-PA 6, *Fiberglass-Reinforced Plastic (FRP) Linings Applied to Bottoms of Carbon Steel Aboveground Storage Tanks*, for information on caulking.

**NOTE** Caulk may be used with thin-film lining systems, as well as thick-film linings where needed to work with surface irregularities.

Consideration should be given to the design of the striker plates beneath the cone roof support columns and internal floating roof legs. Abrasion may occur from contact between the legs and the tank bottom. While coatings may be required on the tank bottom, a steel striker plate that is fully seal-welded will act as protection of the tank bottom. Coatings may or may not have to be continuous beneath the legs, depending on the details concerning the installation of striker plates. If striker plates are not installed, a provision must be made (e.g. protective shoes or similar) to protect the coating if the roof lands. When cable-suspended roofs are installed, this detail is no longer a consideration.

#### 6.6.7 Upset Conditions

The degradation of a lining is a complex process and, unlike the steel that is to be protected, degradation is not readily quantified by a corrosion rate. A relatively short-term exposure to an unusually aggressive environment

can cause irreversible damage to a lining, compromising the protection afforded to the steel. For this reason, a lining must resist potential upset conditions in addition to the usual service environment.

## **6.7 Selecting Internal Linings for Tanks Storing Alternate Fuels**

### **6.7.1 General**

Recent changes in regulations have resulted in the petroleum industry being required to accommodate, handle, and store products that are not petroleum-based. These products fall into two broad categories:

- 1) Biofuels;
- 2) Solvents, i.e. ethanol and methanol.

The owner/operator should both evaluate the type of product to be stored and consult the lining manufacturer to determine the most effective lining system.

### **6.7.2 Internal Lining for Biofuels**

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels. While it acts as a substitute or an additive to conventional petroleum-based diesel fuel, it is chemically different.

In addition, there are various classifications of biodiesels ranging from B2 to B100 and different manufacturing processes. While the past decade has shown that organic linings have been performing adequately with the storage of biofuels, it is important to verify the compatibility of the proposed internal lining with the coating manufacturer. The use of biofuel manufacturer-supplied SDSs as well as past performance of a given lining in similar service should be beneficial in verifying lining suitability. Samples of biofuels to be stored can be laboratory tested for presence and amount of solvents, including ethanol and methanol, which can have deleterious effects on the lining materials. The presence of methanol in trace amounts can often interfere with the performance characteristics.

### **6.7.3 Internal Lining for Solvents**

Identifying suitable organic linings for ethanol service has been an ongoing challenge to the industry. Ethanol itself is not especially corrosive, but organic linings have been recommended as a method of reducing the risk of stress corrosion cracking (SCC) that has been found to be related to ethanol storage. Many studies to date have been performed to identify the source and cause of SCC when storing ethanol but are inconclusive and the results are difficult to apply to field conditions.

While many coating manufacturers have identified coatings that they recommend for ethanol application based on laboratory investigation and testing, the reality is that field conditions differ from laboratory conditions for several reasons outlined below. Certain contaminants in ethanol can cause premature failure of the lining, more so than with petroleum products.

#### **6.7.3.1 Contamination in Ethanol**

Depending on the source of the ethanol and the quality of the processing, the ethanol may contain other solvents or organic compounds. In addition, when transported by ship or railcar, if there is no guarantee of dedicated tanks, vessels, or railcars for exclusive ethanol transportation, the potential exists for many other chemical contaminants to enter the stream. Many of these contaminants, even in minute quantities, can have an adverse effect on the internal lining performance.

In the transfer from the manufacturing source to the final storage location, there is opportunity for water to mix with the ethanol either from the transportation or even from the storage process. Water is miscible with ethanol,

unlike petroleum products which will separate out from the water. Too much water entrained in the ethanol can affect lining performance.

Consequently, the linings that are recommended for 100 % ethanol storage are not necessarily tested for fuel grade ethanol that is stored.

#### **6.7.3.2 Denaturants in Ethanol**

Ethanol is most often stored in a denatured state due to regulations that affect the taxation of potable ethanol. Denaturants vary widely with respect to chemistry. Often the denaturant chemicals are not stated or identified, and even when identified, a review of safety data sheets (SDS) yielded a wide range of denaturants. Consequently, the product being stored is often not neat ethanol, but a blend of ethanol with an unknown or potentially damaging denaturant that is allowed in fuel grade ethanol specifications. It is also possible that the unknown denaturant would not be compatible with the lining, even though the lining material is compatible with 100 % ethanol.

#### **6.7.3.3 Critical Factors for Effective Long-term Performance of Linings for Ethanol**

Items that influence performance of organic polymeric coatings include:

- 1) chemical structure and composition of the resins;
- 2) application thickness;
- 3) curing temperatures;
- 4) curing time;
- 5) quality of weld preparation;
- 6) ventilation during application and cure;
- 7) extent, depth and shapes of surface pits;
- 8) environmental conditions in the tank including humidity and temperatures of atmosphere and substrate;
- 9) cleanliness of substrate (degree of blast);
- 10) presence of contaminants, e.g. chlorides, sulfides, diesel, detergents, dust, etc.;
- 11) surface profile depth and angularity.

Because solvents are chemically aggressive, any shortcoming in the procedures during lining application, no matter how minor, can lead to premature lining failure.

Many locales require ethanol tanks to be decommissioned and repaired/lined during winter months. Most organic coatings cure best at 50 °F (10 °C) and above. Often the substrate temperatures and ambient conditions do not meet these criteria without artificial heat being added. Heating often results in differentials of temperature throughout the substrate due to limitations on the location of the heat sources, ambient and soil temperatures, presence of ice beneath the tank bottom, sunlight differences on each side of the tank shell, and other factors. As a result, coatings may not be properly or adequately cured on all the surfaces that have been lined. Multiple random tests may be required to confirm adequate cure.

Manufacturers have designed coatings that can be applied and cured at temperatures below 50 °F (10 °C) without the need for supplemental heat. Despite the claims and technology advances, to date, there have been challenges in providing adequate crosslinking with these coatings for successful solvent service.

Unfortunately, because the tank linings are not subject to inspection for many years as determined by API 653 and state and local regulations, the performance and effectiveness of the internal linings often cannot be determined for an extended interval of time.

#### **6.7.3.4 Stress Corrosion Cracking (SCC) and Ethanol Storage**

In addition to application of protective linings to welds to mitigate SCC, the act of abrasive blasting has been demonstrated to relieve stress in welds. Because abrasive blasting is required to achieve the surface cleanliness required for an internal lining, one unintended consequence of the process is stress relief of welds. Protective linings adds an additional layer of protection against SCC.

#### **6.7.3.5 Consideration of IOZ for Ethanol Service and API 653**

Historically IOZ has been the lining of choice for ethanol service. It has proven to be effective after many years of field experience. Because API 652 and API 653 historically did not consider IOZ as an internal lining for petroleum products, it was overlooked for application when ethanol became introduced in the petroleum industry as a blend component for fuels instead of being stored as a commodity.

Four conditions need to be satisfied in order to claim zero product-side corrosion rate for purposes of the API 653 inspection interval calculation:

- 1) The tank bottom must be new steel or less than moderately pitted.
- 2) The IOZ must be properly applied in accordance with the manufacturer's specifications.
- 3) The manufacturer must have recommended their IOZ for the specific ethanol product stored.
- 4) The tank must only be allowed to contain fuel grade ethanol in dedicated service until the next out-of-service inspection.

## **7 Surface Preparation**

### **7.1 General**

As recommended in the scope of this document, NACE No. 10/SSPC-PA 6 and NACE No. 11/SSPC-PA 8 should be considered when determining specific criteria for surface preparation and lining application. Following is a general outline of surface preparation considerations covered in these referenced documents.

Surface preparation is a critical part of the lining application. Continuous immersion is a severe exposure. Inadequate surface preparation is a major cause of lining failure. Surface preparation is performed to provide the appropriate combination of surface cleanliness and surface profile, or the anchor pattern (see 7.5) required to establish good chemical and mechanical adhesion of the lining resin to the steel substrate. Generally, abrasive blast cleaning to a white metal finish (NACE No. 1/SSPC-SP 5) is desired. Abrasive blast cleaning to a near-white metal finish (NACE No. 2/SSPC-SP 10) is often specified as the minimum degree of surface cleanliness. For small areas, SSPC-SP 11 is often desirable to avoid damage to the surrounding lining that may be in very good condition. Use of power tools to meet SSPC-SP 11 requirements must include the use of abrasive disks, flapper wheels, needles, or steel points that provide the specified anchor profile and must be followed by solvent wipe per SSPC-SP 1 to remove oil contaminants from the power tool.

To facilitate inspection and to ensure good adhesion of the lining, surface preparation by abrasive blasting and/or power tools should extend several inches beyond the area to be lined. This practice of framing the area where lining is to be applied helps to ensure that unprepared steel and unprepared adjacent remaining coating is not inadvertently coated.

## **7.2 Pre-cleaning**

### **7.2.1 Residue Removal**

Prior to abrasive blasting, all hydrocarbon residues such as oil, tar, and grease must be removed from the area to be lined. Solvent cleaning (see SSPC-SP 1) and high- or ultra-high-pressure water or steam cleaning using the proper chemicals are effective methods of accomplishing complete hydrocarbon removal. Cleaning is typically followed by a clean, fresh water rinse to ensure complete removal of cleaning chemicals.

### **7.2.2 Soluble Salts**

It is important to note that typically, abrasive blasting is not effective in the removal of soluble salts and can actually “fold” into or trap soluble salts in the steel substrate. The presence of soluble salts on the steel can adversely affect the performance of a lining, resulting in blistering by osmosis. Consideration should be given to a field evaluation for the presence of soluble salts whenever there is the possibility of such contamination. SSPC Guide 15 describes common methods for this evaluation. The use of high pressure and ultra-high-pressure water jetting can reduce soluble salt contamination; however, an acceptable reduction may not occur due to the presence of chemically adsorbed molecules. NACE and SSPC have developed specifications to be used for substrates that already possess a surface profile and do not require abrasive blasting or for contaminated surfaces prior to abrasive blasting.

Commercial products assist in reducing the presence of soluble salts if they are found on the substrate during testing. Follow the manufacturer’s recommended procedures for use of these products. Be sure to remove any resulting residuals and then always test again following any treatment method.

### **7.2.3 Water Quality**

Water that is used for surface cleaning should be of adequate purity and quality that it does not preclude the surface from meeting the surface cleanliness criteria, including soluble salt limits. Where saltwater is used for hydrostatic testing, the substrate should be tested for contaminants prior to abrasive blast and then again prior to the start of the coating application process. Specific cleaning and treatment may be required to return the substrate to acceptable condition.

## **7.3 Bottom Repair and Subsequent Weld and Component Preparation**

The repair of perforations of the steel tank bottom shall be performed by welding of steel patch plates or replacement of bottom plate. Epoxies and other nonsteel shall not be used to repair perforations. API 653 should be consulted for information on tank bottom repair.

Welds should be inspected before and after blast cleaning. All sharp edges and protrusions should be ground to provide a smooth surface that can be completely and uniformly covered with the lining material. Sharp edges and protrusions may be caused by weld spatter, sharp weld crests, undercutting of the weld, arc burns, erection clips, plate joints, burrs, and gouges. Chipping, followed by grinding, can be used to remove sharp edges or in some cases, grinding alone may be adequate.

NACE SP0178 can be used to specify the surface finish of welds and steel member or component edges and corners. Typically, weld finish “C” or “D” is specified where feasible.

## **7.4 Surface Cleanliness**

The surface to be lined should be of the specified level of cleanliness at the time the lining is applied. If the surface is degraded or contaminated subsequent to surface preparation and before lining application, the specified level of cleanliness should be restored before lining application. Holding primers or first coating applied to the prepared surface shall be applied before the surface has degraded. When using recycled media on tank linings it may be difficult to ensure that the surface is clean. Recycled media may collect and concentrate the contaminants, which are often difficult to detect by inspection, with each successive recycle process and then impinge these

contaminants into the steel profile. Owner/operators should weigh the benefits of recycled media against the risk of having surface contamination that may interfere with the life of the internal lining.

### **7.5 Surface Profile or Anchor Pattern**

The abrasive used for blasting should be selected to produce the necessary profile depth, sharpness and angularity of the anchor pattern, for the lining to be properly applied. The lining manufacturer's recommendation for surface profile depth must be achieved to optimize the mechanical adhesion of the lining to the steel tank bottom. The anchor pattern required for linings is typically 1.5 mils to 4.0 mils (38  $\mu\text{m}$  to 102  $\mu\text{m}$ ) and generally increases with the thickness of the lining. To achieve adhesion necessary for long-term performance, it is important that the anchor pattern is sharp and angular. It may be difficult when using recycled media prior to tank linings to ensure a uniform proper profile depth, as well as a proper degree of sharpness and angularity. Owner/operators should weigh the benefits of recycled media against the risk of not having adequate surface profile that may be required for internal linings.

### **7.6 Air and Abrasive Cleanliness**

The abrasive and compressed air supply used for abrasive cleaning of tank bottoms should be free of contaminants such as water-soluble salts, dirt, clay, oil, and grease (per SSPC-AB 1, AB 2, AB 3, and ASTM D4940 and ASTM D4285, as appropriate). If present in the blasting abrasive, small amounts of these contaminants may be delivered to the steel surface during the cleaning operation. This contamination will reduce the useful life of the lining. For tank linings, the allowable levels of water-soluble contaminants, from a conductivity standpoint, are normally reduced from those specified in SSPC-AB 1, AB 2, and AB 3 to ensure appropriate levels for these lining systems. Compressed air quality should be evaluated in accordance with ASTM D4285.

### **7.7 Removal of Salts**

Corrosion-inducing anions from water-soluble salts, if present, may be lodged on the substrate surface. Section 7.2.2 covers soluble salts and their treatment. Testing for the presence of chloride and other contamination should be considered prior to proceeding with any lining installation.

### **7.8 Removal of Dust**

Spent abrasive, as well as spent abrasive dust, must be removed from surfaces prior to coating application. Standard practice has been to blow-down surfaces with clean, compressed air, and use vacuum cleaning methods. Follow OSHA regulations when using compressed air for cleaning surfaces. Vacuum cleaning methods have proven to be more efficient. ISO Standard 8502-3 may be used to determine the effectiveness of cleaning methods.

## **8 Lining Application**

### **8.1 General**

When a holding primer is used, it is important that it is applied according to the manufacturer's instructions for film thickness, as excess thickness may have an adverse effect on intercoat adhesion and will adversely affect the performance of the coating system. Recoat windows, based on actual temperatures, must be strictly followed when using multiple coat systems. Actual temperatures may be that of the substrate or ambient air, and whichever is more conservative shall govern the determination of recoat window time. If coatings exceed the suggested recoat windows, then the coating must be properly prepared in accordance with the manufacturer's recommendations prior to proceeding to any subsequent coats or processes.

Subsequent coats must be applied within the recoat interval recommended by the lining manufacturer, for the temperatures involved. The inspector shall ensure the contractor follows the manufacturer's specifications for each product, as well as the complete coating system. The inspector shall record and report to the owner/operator the conditions and the time intervals. Generally, the recommendations and procedures prescribed in SSPC-PA 1 should be followed. After adequate curing of the completed lining, holiday testing (as described in 9.3.4)

should be performed. Any defects should be repaired in accordance with the coating material manufacturer's recommendations and the written specification.

## **8.2 Guidelines for Lining Application**

SSPC-PA 1 provides general guidelines for good lining application practice. Proper on-site storage conditions, mixing, application, and curing of the lining are essential procedures, and the lining manufacturer's recommendations should be followed. Any differences between the owner/operator's specification and the lining manufacturer's recommendations should be resolved before beginning the job.

## **8.3 Temperature and Humidity Control**

The temperature of the steel surface should conform to the lining manufacturer's recommended application and curing ranges. As a rule, the surface temperature must be at least 5 °F (3 °C) above the dew point temperature in the tank, and the relative humidity should be below 80 % at the steel surface. If the surface temperatures and/or humidity levels are expected to deviate from the recommended range, climate control equipment should be employed to ensure the proper conditions are maintained. It should be noted that durations of surface preparation, lining application, and cure may be continuous over a 24-hour period or longer. If so, the required environmental conditions must be maintained around the clock. Owner/operator operations may interfere with continuous use of environmental control equipment. These operational considerations should be reviewed prior to the execution of the tank lining project.

NACE 6A192/SSPC-TR 3 provides guidance on the use of dehumidification and heating equipment for environmental controls during tank lining work.

Climate control equipment is also used to advantage by protecting workers from heat stress during hot summer months. Improved productivity, due to better working conditions, is a secondary benefit.

## **8.4 Lining Thickness**

Inadequate film thickness in any location will not provide adequate film build or protection and can result in reduced service life of the lining. Excessive film thickness, beyond the manufacturer's recommended range, can compromise lining adhesion and film integrity. Excess primer thickness is a common cause of failure of thick-film lining systems. Individual coat and the complete lining thicknesses shall be in accordance with the lining specification. Excess thickness of any particular coat shall be remedied in accordance with the manufacturer's recommendations prior to proceeding to any subsequent coats or processes. Changing or alternating colors between coats can aid in ensuring uniform film build and thickness.

## **8.5 Lining Curing**

Improper application and inadequate curing time are major causes of premature lining failure. The adhesion and integrity of the film are adversely affected if a lining has not been applied and cured properly. Prior to removing forced ventilation or closing the tank, the lining should be completely cured to obtain optimum service life. Refer to the coating manufacturer to determine the proper cure time and temperature. The proper curing conditions should be ensured for the full duration of the cure time. The proper conditions for curing of the lining may be accomplished by circulating warmed, dehumidified air in accordance with the lining product manufacturer's recommendations for that specific lining system (see 8.3 and NACE No. 10/SSPC-PA 6). In certain circumstances, forced curing may be used to accelerate the process, provided the manufacturer's recommendations are strictly followed and the increased heat used to force cure the lining does not cause damage to the seal or other tank components.

The owner/operator shall not rely on estimates of time and temperature. The owner/operator and the applicator shall ensure that the lining is fully cured prior to returning the tank to service.

Solvent-borne linings require forced ventilation of the air space adjacent the lining. As the heavier-than-air solvents evolve from the wet lining, they will remain over the lining, impeding the completion of this process.

Dissipation of solvent vapors must occur so enough solvent can evolve from the film to achieve a level of cure necessary for hydrocarbon or chemical resistance.

## **9 Inspection**

### **9.1 General**

Independent quality assurance inspection is highly recommended to oversee the contractor's quality control process. It shall be fully ensured that the criteria in the lining specification have been met. The lining installation should be inspected throughout all phases of the work and upon completion of the work. The performance life of a lining is directly related to the quality of the surface preparation, application, and curing, as ensured by a thorough overall inspection. Documentation should include daily inspection records to capture the project activity, issues, and compliances per the written procedures and specifications.

Project records should be made to briefly describe the products and procedures that were used during installation of the lining. These records will be important the next time the tank is opened to compare the lining product and installation process with the actual observed lining performance. Records will also be valuable if repairs are needed and a repair product and repair procedure has to be determined and developed.

### **9.2 Qualification of Inspection Personnel**

All lining inspectors should be either NACE or SSPC certified or should have demonstrated a thorough knowledge of coating and lining practices, procedures, inspections, testing and documentation.

### **9.3 Recommended Inspection Parameters**

#### **9.3.1 Surface Cleanliness and Profile**

Quality assurance and quality control personnel shall verify that the recommended practices reviewed in Section 7, as well as the manufacturer's specifications, are strictly followed.

#### **9.3.2 Film Thickness**

Inspection shall verify that as the lining is applied, wet film thickness measurements are being made for each coat in accordance with ASTM D4414. After the lining has cured adequately to allow handling, DFT measurements should be made in accordance with the specified method to determine DFT in accordance with SSPC PA 2, if not otherwise stated.

#### **9.3.3 Final Cure**

If specified to aid in determination of degree of cure, hardness of the lining should be measured in accordance with the manufacturer's recommendations, following any specified ASTM methods. It should be noted that this test could be destructive to organic resin linings that are not adequately thick, hard, and/or cured.

#### **9.3.4 Lining Discontinuities**

Holiday testing of thick-film linings shall be performed with a high-voltage detector in accordance with NACE SP 0188. Holiday testing of thin-film linings should be performed with a low-voltage (67.5 volts) wet sponge detector. When testing with high-voltage detectors, it is important that the voltage be properly set in accordance with the manufacturer's recommended volts per mil and that the film thickness properly matches the specified thickness. Otherwise, damage may occur from the testing operation. Also, nothing in this document shall preclude the testing of a thin-film lining using a high-voltage detector, if there are temperature considerations, provided that the voltage is properly set to correspond with the actual film thickness.

## 10 Evaluation, Repair, and Replacement of Existing Linings

### 10.1 General

A properly selected and applied tank bottom lining should be expected to provide a minimum service life of 20 years. Some lining systems, most notably thick-film laminates, have provided 25 to 30 years of service life. Lining “failure” is not well defined and fitness-for-service is not well established for polymeric coatings. Linings degrade with time. Blistering is a common mode of lining deterioration. However, blistered linings may remain fully functional, providing corrosion protection to the steel for many years. Lining degradation does not necessarily translate to putting the steel at significant corrosion risk.

When available, tank bottom linings should be thoroughly inspected to assess their condition and determine the need for repairs or replacements. Timely maintenance can keep repairs to a minimum and greatly extend lining service life. Care should be taken not to damage the lining (especially thin-films) during cleaning, inspection, and repair procedures. API 653 provides guidance for visual in-service and detailed out-of-service inspection and repair methods for tank components. These inspections may reveal conditions that necessitate lining repair, which are not covered in API 653. All repairs to the tank should be completed before any repair or replacement of the lining. It should be recognized that the longer a lining has been in service, the shorter its remaining service life.

### 10.2 Evaluation Methods

Lining evaluation methods include the following:

- a) visual inspection;
- b) adhesion measurement;
- c) audible testing (to find areas of delamination on reinforced thick-film linings via tapping with a solid metal object);
- d) physical examination of lining sample, including possible laboratory testing (to determine permeation by the tank’s previous product, film thickness, brittleness, and/or adequacy of cure)

Holiday testing is not typically recommended for linings that have been in previous service, since the presence of moisture in the film can cause damage when exposed to voltage. In some instances, this has been successfully achieved after the tank has remained open and the lining has been exposed to normal ventilation for several months. Consultation with the coating manufacturer prior to attempting this type of inspection is necessary.

**NOTE** A holiday test requirement may pose a challenge, as many regulatory agencies rely on the holiday test to establish the efficacy of a lining that has been in service. If a lining that has been in service fails the holiday test in areas that are not obviously deficient, the holiday test should not be used as pass-fail criteria. In addition, adequate cleaning of the tank is critical to successful and meaningful holiday testing of tank linings that have been in service.

### 10.3 Evaluation Criteria for Linings

Evaluation of existing tank linings should be based on the following criteria.

- a) How long has the existing lining been in-service?
- b) How well has the existing lining performed to date?
- c) What is the desired service life of the lining? (i.e. how long must the lining do its job before it will be inspected and receive required maintenance).
- d) What are the intended exposure conditions? (i.e. intended service of the tank, operating temperature, whether water will be present, whether other contaminants or chemicals will be present and their concentrations).

e) What are the specifications and characteristics of the existing lining?

#### **10.4 Evaluating Serviceability of Existing Linings**

The evaluation methods listed in 10.2 should be used to determine if an existing lining is suitable for service. Blistering, cracking, crazing, discoloration, and areas of missing lining are modes of degradation that can be detected by visual inspection. However, these types of degradation may not be readily visible unless the bottom is thoroughly lighted, cleaned, and accessible. Other modes of degradation that may not be readily visible are permeation of the lining by hydrocarbon, softening, wicking, delamination, disbanding, and loss of thickness due to abrasion and/or chemical attack. These modes of degradation may require the use of the other examination techniques in 10.2 to be detected. Following the examinations, the evaluator should apply the criteria in 10.3 to determine if the lining is suitable for service.

#### **10.5 Determining the Cause of Lining Degradation/Failure**

If lining degradation is detected, the cause and extent of coating degradation must be established, as well as whether the existing lining is suitable for a repair. When evaluating the condition of an existing lining, one should consider whether deterioration is premature or whether the lining has achieved its anticipated performance life.

If degradation or failure of a lining is premature, it is important to understand and address the cause of such degradation prior to determining whether the lining should be repaired, refurbished, or completely replaced. A review of the tank's operating history and a visual examination of the lining should be conducted to determine whether the problems were a result of environmental attack, local mechanical damage, and/or if inadequate surface preparation or improper lining installation were contributing factors.

#### **10.6 Lining Repair and Replacement**

##### **10.6.1 General**

The term "repair" of a lining is typically used when either portions of the lining will be replaced or when all or a portion of the lining will be top coated. The term "replacement" is used when all the existing lining is completely removed to the steel substrate and a new lining is applied.

##### **10.6.2 Lining Repairs**

###### **10.6.2.1 Localized vs General Degradation**

The amount of the bottom area in which the lining has failed or deteriorated and the size of the tank are significant factors in determining whether all or a portion of the lining should be repaired or replaced. If only a few small areas require lining repair and the tank is fairly large, it is usually more cost effective to use power tools to achieve the required level of cleanliness and anchor profile depth rather than to introduce abrasive into the tank. For thin-film linings in good condition, open blasting in a tank is not advised as the removal of the abrasive material often damages the existing lining. When new patch plates or other weldments are installed, it is important that the patch plates be properly cleaned, properly anchor profiled, and transition profiled in accordance with the lining manufacturer's requirements for immersion service. This is especially true when power tool cleaning is used in lieu of abrasive blast cleaning on the new plates.

###### **10.6.2.2 Spot Repairs**

Spot repairs are made when there are only localized failures, such as cracks, blisters, pinholes, disbonding, delamination, or mechanical damage. The existing failed lining is removed, the surface is prepared to bare metal or to a tightly bonded lining, and new lining materials are applied at the failed areas only.

###### **10.6.2.3 Top Coating an Existing Lining**

Reinforced thick-film linings can be top coated to extend the life of an existing coating that has good adhesion and integrity. The topcoat is applied to ensure the fibers are not exposed to the product. Accepted practice

involves removal of contaminants, then brush-blasting and application of one or more topcoats. To ensure good adhesion of the repair, the lining manufacturer should be consulted to assess the compatibility of the topcoat material with the existing lining and anything absorbed by the existing lining. Thin-film, reinforced thick-film, and thick-film unreinforced linings may be top coated as part of a repair procedure in certain situations. The decision to topcoat will depend on the condition of the existing coating and the extent of holidays and coating repairs required as well as the desired duration to the next out-of-service inspection.

#### **10.6.2.4 Repair and Top Coating Specifications**

Consideration should be given to the lining manufacturer's recommendations when developing the repair specifications. All differences between this RP and the specification, procedure, inspection and test plan, and manufacturer's recommendations should be resolved before starting any lining repairs or topcoating.

#### **10.6.2.5 Lining Removal Methods**

Considerations that affect the method of lining removal are:

- a) size of lining repair or replacement area;
- b) type of lining;
- c) whether steel is contaminated with oil or chemicals;
- d) the lead content of the liner and regulatory requirements for testing, removal, and disposal; and
- e) extent to which the steel bottom requires mechanical repair.

If the mode of degradation of a reinforced thick-film lining included disbondment or delamination, it should be noted that manual removal of the improperly adhered laminate may be more cost effective than abrasive blasting.

Care must be taken with manual and power tool removal of linings to avoid damage from gouging to the steel bottom and lower shell substrate. Alternate removal techniques such as electromagnetic induction stripping and ultrahigh water blasting may be more effective in removing failed laminates and should be considered as an alternative to power tool removal or abrasive blasting.

#### **10.6.2.6 Sequence of Contamination Removal vs Lining Removal by Blasting**

Regardless of whether a lining will be completely removed and replaced or will receive spot repairs or top coating, it is important to detect and to identify visible and/or non-visible contaminants. If such contaminants include chlorides or hydrocarbons, abrasive blasting without first removing the oily hydrocarbon may adversely affect the new lining's adhesion. If oily hydrocarbon has contacted the steel, it is critical that the contaminant be removed before abrasive blasting.

## **11 Maximizing Lining Service Life by Proper Material Selection and Specification**

### **11.1 General**

Corrosion on the product side of the tank bottom is a factor in determining a proper interval between tank inspections. Corrosion protection afforded by an internal lining mitigates the corrosion rate on the product side of the tank bottom and allows the service interval between tank inspections to be maximized.

It should always be recognized that linings do not last forever. Typically, they become less effective over time. The deterioration rate can be fast or slow. Experience has shown that some linings have failed in less than a year and some linings have been found to provide adequate corrosion protection after more than 20 years of service. The various aspects of tank bottom soil-side corrosion and corrosion control systems also have to be considered.

## 11.2 Lining Material Selection

Unless the specifier has experience with a given lining material's performance in a given service, the owner/operator should require verifiable test data along with references supporting the considered material's suitability for the intended service and operating conditions.

## 11.3 Written Specification

The specification should be job-specific and include a detailed scope, a specific description of the components to be lined, and a list of all responsibilities and tasks of the contractor. As a minimum, the specification should address the relevant aspects covered by NACE No. 10/SSPC-PA 6 and NACE No. 11/SSPC-PA 8, as follows:

- a) steel plate preparation and weld surface quality;
- b) surface preparation, including criteria describing the abrasive; steel cleanliness; anchor profile; removal of dust, salts; other contaminants; and waste handling and removal;
- c) environmental controls and ventilation;
- d) control of solvent vapors;
- e) wet film thickness measurements;
- f) applicable curing and heat curing requirements;
- g) DFT range required and criteria as to method of measurement;
- h) holiday testing requirements;
- i) method for determination of cure;
- j) final inspection requirements;
- k) labeling or stenciling requirements for lining identification;
- l) any other requirements; and
- m) surfaces to be coated, including height of coating on lower shell and/or vapor space.

## 12 Health, Safety, and Environmental

### 12.1 General

Prior to the application of internal tank linings, proper training of employees regarding health, safety, and environmental procedures and the provision of the necessary supervision and/or inspection throughout the progress of the job is required. Guidance on federal training requirements is given in OSHA 2254. A documented hazard evaluation, as outlined in OSHA 29 *CFR* 1910.132, is required to determine what personal protective equipment (PPE) may be needed.

Users of this RP are responsible for reviewing appropriate health, safety, environmental, and all associated regulatory documents along with determining their applicability in relation to this RP prior to its use. This RP does not address all potential health and safety issues, or environmental hazards associated with the use of materials, equipment, and/or operations that are described, detailed, or referred to within this RP. Users of this RP are also responsible for establishing appropriate health, safety, and environmental protection practices, in consultation with appropriate regulatory authorities, if necessary, to achieve compliance with all existing applicable regulatory requirements prior to the use of this RP.

General health and safety concerns are emphasized in 12.2 through 12.4.

## 12.2 Tank Entry

All necessary precautions to protect personnel shall be taken before entry and while working in a storage tank. Working in a confined space such as a petroleum storage tank presents special respiratory, explosion, and fire hazards that must be addressed. Tank entry and/or hot work permits should be issued and enforced, as local work rules and applicable regulations require. Guidelines for issuing permits and preparing a tank or confined space for entry are detailed in API 2015, including evaluation of the atmospheric hazards and lockout-tagout of process lines and equipment. Federal, state, and local regulations (or international regulations if applicable) pertaining to confined space entry also should be reviewed and followed to ensure conformance. In the U.S., OSHA 29 *CFR* 1910.146 governs permit-required confined spaces under the OSHA general industry standard.

## 12.3 Surface Preparation and Lining Application

Health hazards are a prime concern during surface preparation and lining application. Proper respiratory equipment and personal protective clothing should be employed where necessary. Information regarding safety precautions and procedures during surface preparation and lining application are found in SSPC Guide 10.

**NOTE** This is the general industry standard for ventilation and abrasive blasting shop operations. Most of the provisions do not apply to field conditions. There is no abrasive blasting standard under OSHA construction standards.

If lining materials containing or previously exposed to lead are to be removed, special precautions are required to protect both the personnel and the environment. The specific requirements for worker protection from lead can be found in OSHA 29 *CFR* 1926.62. OSHA construction industry standard is more stringent and applies to most tank repair work activities.

## 12.4 Manufacturer's Safety Data Sheets

The chemical constituents of high-performance internal tank lining materials can present health hazards to workers if not handled properly. Safety data sheets (SDS) concisely inform employees about the materials being used so that they can protect themselves and respond properly to emergencies.

The purpose of an SDS is to inform the worker of the following:

- a) a material's physical properties, which make it hazardous to handle;
- b) the type of personal protective equipment needed;
- c) the first aid treatment necessary if exposed to a hazard;
- d) the planning needed for safely handling normal operations, as well as emergencies such as spills and fires;
- e) the appropriate response to accidents.

The applicable SDS should be consulted for all materials before conducting any work.

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